ANALYSIS OF EXISTING EFFECTIVENESS AND METHOD TO ENHANCE THE LIGHTNING, SHIELDING AND EARTHING PROTECTION SCHEMES APPLIED ON THE PARIT RAJA'S TELECOMMUNICATION TOWER SYSTEM

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A project report is submitted in partial fulfillment of the requirements for the award of the Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
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JANUARY, 2013

DEDICATION

Special dedication to

my beloved parents, family, supervisor, technicians, friends and personal who have encouraged, guide and inspired me throughout my journey of education.

Thanks for all the support.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful

First and foremost, I would like to express my deepest gratitude to DR. MD. NOR RAMDON BIN BAHAROM, my project supervisor for giving me the continuous advices, supports and necessary information needed to accomplish this project.His immense knowledge and guidance helped me in all the time of project and writing of this thesis.

My sincere thanks also goes to the great technicians of Electrical and Electronic Laboratories of UTHM for their encouragement, consideration and cooperation throughout this project.

Last but not least, I would like to thank all of my friends and everybody that involved in the progress of this project for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the supports that were given.

I humbly thank you.

Ct Valkyis binti Mohd Kasim

ABSTRACT

Lightning, one of nature's most destructive forces, continues to wreck havoc on lives and property especially in today's electronic environment. It has been shown by field experiences that telecommunication towers are one of the preferential points for direct lightning strike. This is mainly connected with the specific features of their construction where the presence of high telecommunication towers and their topographical location mostly at an open area or at hills. The potential of lightning strike toward communication tower is high. A telecommunication tower located at Parit Raja town was chosen as a case study. The location of the tower is good to channel the coverage toward the community. Unfortunately this tower is very vulnerable to lightning strike and can giving impact to the surrounding buildings located nearby the tower itself such as mosque, petrol pump, post office and the Bank Simpanan National (BSN) bank. This thesis presents work that look at the current protection scheme against the lightning strike and the effect on a telecommunication tower system and the surrounding. Analysis study had been made towards existing protection component or system and their effectiveness in mitigating the lightning strike impact on the Parit Raja tower system. The investigation of the lightning protection system used by the communication tower is sufficient enough to direct the overload voltages of a lightning strike. Also, the analysis on the existing grounding earthing system is able to accommodate and dissipate the surge current to the earth. The method such as rolling sphere and cone protection had been used to identify the safety area on the site due to direct strike. Some suggestions to enhance the tower system protection such as installation external ground bus bar, radial system, and new installation for connection of coaxial cable and underground cable. Overall from this project, the weaknesses of system protection were identified in the tower Parit Raja and the proposal as improvement for the protection scheme in the future.

ABSTRAK

Kilat merupakan salah satu tenaga alam semula jadi yang mampu meragut nyawa dan menghancurkan harta benda terhadap persekitaran elektronik sekarang. Menara komunikasi merupakan salah satu tarikan kilat yang mudah untuk disambar oleh kilat disebabkan ciri pembinaanya yang terletak di kawasan tinggi dan terbuka. Potensi bagi menara komunikasi untuk disambar oleh petir adalah tinggi. Satu menara komunikasi yang terletak di Parit Raja telah dipilih sebagai kajian kes. Lokasi menara itu adalah sangat strategik bagi menyalurkan liputan komunikasi kepada masyarakat komuniti setempat. Malangnya, menara ini sangat terdedah terhadap petir dan akan member kesan terhadap bangunan yang terdekat seperti masjid, petrol pam, pejabat pos dan Bank Simpanan Nasional (BSN). Tesis ini membincangkan sistem perlindungan terhadap petir dan kesannya terhadap sistem menara komunikasi serta kawasan sekitarnya. Analisis telah dibuat terhadap perlindungan komponen asal dan keberkesannya dalam mengurangkan impak oleh panahan petir terhadap system menara pada pada Parit Raja itu. Siasatan terhadap system perlindungan kilat yang digunakan oleh menara komunikasi mungkinkah mencukupi bagi mengarahkan voltan beban kilat. Analisis terhadap system pembumian asal juga dilakukan bagi menampung dan menyisihkan lonjakan arus elektrik ke bumi. Kaedah seperti “Rolling Spohere”dan “Kon Method” telah digunakan untuk mengenal pasti kawasan yang selamat disebabkan lonjakan arus. Beberapa cadangan bagi meningkatkan system perlindungan menara seperti pemasangan “external ground bus bar”,sistem jejarian dan pemasangan kabel bawah tanah. Keseluruhan projek ini, kelemahan oleh system perlindungan telah dikenal pasti di menara ini dan cadangan sebagai penambah baikan bagi skim perlindungan di masa.

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LIST OF SYMBOLS AND ABBREVIATIONS

mm	-	Millimeter
m	-	Meter
BSN	-	Bank Simpanan Nasional
MGB	-	Main Ground Bus Bar
EGB	-	External Ground Bus bar
TGB	-	Tower Ground Bus bar
UTHM	-	Universiti Tun Hussein Onn Malaysia
TNB	-	Tenaga Nasional Berhad
IEEE	-	The Institute of Electrical And Electronics Engineer
IEC	-	International Standard

CHAPTER I

INTRODUCTION

1.0 Introduction

Lightning, one of nature's most destructive forces, continues to wreak havoc on lives and property especially in today's electronic environment. Lightning strikes the earth in excess of 50 times per second [1]. On average, a lightning strike contains approximately 50 million volts carrying 18,000–20,000 amperes of current, but strikes with up to 300 million volts and 200,000 amps are not that uncommon [2]. Lightning can be defined as high current electric discharge which built up on cloud near the surface of the earth during atmospheric disturbances [3].

It has been shown by field experiences that telecommunication towers are one of the preferential points for direct lightning strikes. This is mainly connected with the specific features of their construction where the presence of high telecommunication towers and their topographical location mostly at an open area or at hills. Because of high altitude of placing radio transmission antennas, lightning strokes to the structures supporting the antennas are relatively frequent.

To protect against this destructive phenomena, a properly designed and lightning protection system is required. The purpose of this project is to analyze the effect of lightning strikes on an existing telecommunication tower system and also to provide the methods to enhance the tower system protection against lightning strikes.

For this, the telecommunication tower located at Parit Raja is chosen as a case study. In summary, this project about is study the system protection on Parit Raja tower against the lightning strike. The analysis of the system protection is based

on the direct and indirect strike as well as investigated the grounding system able to withstand the impact of the lightning strike.

1.1 Problem statement

Telecommunication system is very important for interaction and communication with others that is far away. Therefore, all the communication equipment needs to be protected because the signal communication originated from the tower communication. Telecommunication towers have high tendency for lightning strike since it basically a tall abject (approximate height) and sometimes placed at the hill area. Further more, quite after we see it being located in the crowded area that surrounded by building or residential (more coverage). The location of the tower is good to channel the coverage toward the community.In Parit Raja communication tower, in the event of shielding failure due to lightning, it might deliver the surge not only to the system equipment, but also to the nearby area. The Parit Raja Tower is near to community area such as the Bank Simpanan Nasional (BSN) bank, mosque, post office, and petrol pumps etc. Therefore, the potential of induce current deliver to this area is high.

In such a case the effects of lightning are twofold. The lightning current flowing through the conducting parts of the whole structures and associated grounding system creates high voltage differences between conductors. This cause a direct and very serious danger, particularly for equipment connected to the grounding system. Some parts of this current may flow directly through the cabling system into the radio-transmission equipment. On the other hand, the same lightning current creates strong electromagnetic pulses, which can generate large over voltages and over currents in wires of electric and electronic systems.

A proper protection system is crucial to keep the equipment and electronic system intact; avoiding system damage and hazard exposure due to the lightning strike. The cost to repair the damage of the electrical equipment requires great sum of amount, especially for expensive equipment such as electronic circuit, industry plan, cable and etc.

Hence, it will be much more beneficial to spend the money in constructing and designing an effective lightning protection system instead of fixing the damage done by the lightning strike to the telecommunication tower.

1.2 Objectives

The project has used the telecommunication tower located at Parit Raja town as a case study. Some objectives have been aimed from this project such as described below.

i. To analyze existing protection component/ system that currently being used their effectiveness in mitigating the lightning strike impact on the tower system.
ii. To provide the solution in enhancing the system protection against lightning strike impact on the tower system.

1.3 Scopes of Project

In order to achieve the mentioned objectives, several works have been highlighted such as:

i. Literature review study covering necessary topic and theory pertaining to the lightning protection system on the telecommunication tower.
ii. Site visit to the Parit Raja's telecommunication tower to investigate the existing lightning protection schemes that being applied.
iii. Conducting the simulation and analysis effectiveness of the site's existing protection schemes with the theoretical design information.
iv. Proposing the enhance version model of lightning protection scheme on the site's tower area.
v. Simulating the proposal model for verification.

1.4 Thesis structure

In Chapter 1 discussed about the problem of the lightning struck to communication tower. Therefore, the plan had been made to identify the objectives and scopes in order to facilitate the project.

In chapter 2, some previous studies have been discussed to obtain clear information and guide for this project. Also, the basic theory in lightning creation, the damaging of the lightning struck, the lightning protection system and the method has been used in lightning protection scheme for enhanced the understanding.

The chapter 3 discussed about the planning of the project to ensure it would be success. The project has divided in two parts respectively. Part 1 focused mainly on gathering the information on the lightning protection system that was currently used.. In part 2, discussion about the current protection system had been identified and the proposal to overcome the weaknesses.

In chapter 4, the Parit Raja Tower communication has been chosen as case study. The analysis and investigate have been made in enhancing the understanding of lightning protection scheme in communication tower. The weakness of the grounding system had been identified based on observation.

In chapter 5, after the weakness of system was identified on Parit Raja tower, some suggestions are proposed to increase the effectiveness of the protection system. The recommendation on the new installation for the external ground bus bar, installation of the cable, the underground cable and the radial system for the better protection are discussed.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

In this chapter, some previous studies will be discussed in order to obtain clear information and guide for this research. Also, the basic theory and method in lightning protection scheme is added for an enhanced understanding. Table 1 shows the number of reference that has been referred in completing this project.

Table 2.1: Review of previous works by other researches

Author	Paper	Description	Contribution to the project
Karol Aniserowicz	Methods of Creation of Lightning Protection Zones Near Tall Telecommunication Structures According to Different National Standards	Presented the problems of creation of lightning protection zones, especially around antenna towers and masts. The designing methods have been compared basing on review of selected standards and the literature [4].	Clarify of methods such as of Rolling Sphere and Cone Protection method according to difference National standard. The creation of lightning protection zones were presented the protection level, efficiency of protection and the angle be achieve using the method both method.

Table 2.1: Review of previous works by other researches (Continued)

Author	Paper	Description	Contribution to the project
Kai Sang Lock	Lightning Protection, Earthing and Surge Protection of Base Transmission Stations	This paper examines the challenges and solutions in the integration of lightning protection, earthing and surge protection for a base transmission station comprising a telecom tower and an equipment cabin, taking into consideration external power source via overhead Lines [5].	Clarify the protection should be considered in the communication tower. Protection against direct lightning strikes includes • Effective earth termination network for discharge of lightning current • Integration lightning protection earthing systems • Extensive bonding to prevent electric shock • Mitigation of ground potential rise • Prevention of conducted surges and into equipment cabin
Dr. Robert A Durham, PE	Lightning, Grounding, And Protection For Control and Communications Systems	Presents of problems that require a different perspective from a new installation. The paper addresses lightning, transients, and radiation that causes problems on programmable logic controllers, distributed control systems, and remote electronic transducers. While complex grounding grids and networks were not often required for analog systems, digital equipment requires a more effective means of maintaining equal potential throughout the facility. The investigation ranges from no air terminals to lightning arrays. The protection problem is compounded when different soils such as clay and rock are encountered. Methods of calculating the grounding circuit resistance are identified [1].	Help in terms of understanding the of lightning strike creation in general, the influence of soil type on the grounding, concepts lightning protection such as air termination, down conductor and ground termination which consists of ring system, radial system and the earth electrode.

Table 2.1: Review of previous works by other researches (Continued)

Author	Paper	Description	Contribution to the project
Teruo Kageyama	Lightning Protection Of Power Equipment For Telecommunication	Lightning protection for power equipment in order to maintain its reliability. The Nippon Telegraph & Telephone Public has been investigated the actual conditions of an invading lightning surge, the grounding impedance, lightning damage, etc. The microwave relay stations and small scale telephone offices which are often damaged by an invading lightning surge. The Nippon Telegraph & Telephone Public further has examined systematic lightning protections of telecommunication power equipment. As a result, it was found that enlargement of arrester capacity, multiinstallation of arresters and grounding surge impedance reduction by using interconnected grounding and by improving the technique for laying grounding wire, etc. [7].	Clarify the the actual conditions of an invading lightning surge, the actual conditions of the grounding system which discharge the lightning surge to the ground, the lightning damage of power equipment and protection method of power equipment against lightning effects.

2.1 Lightning over Voltages in Communication Site

The lightning over voltage is known as fast front over voltages (FFO). Essentially, the lightning over voltages is generated by the lightning strike [8]. Overvoltage in communication station occurs occasionally. The lightning overvoltage is the major one which can reduce the equipment life and leading to equipment failure. In communication site, the over voltage can be formed in three different ways; direct lightning strike to the antenna or radio transmission line (microwave), lightning strike to the lightning rod or to the tower, and lightning strike to nearby ground and induce voltages on the communication building as illustrated in figure 2.1.

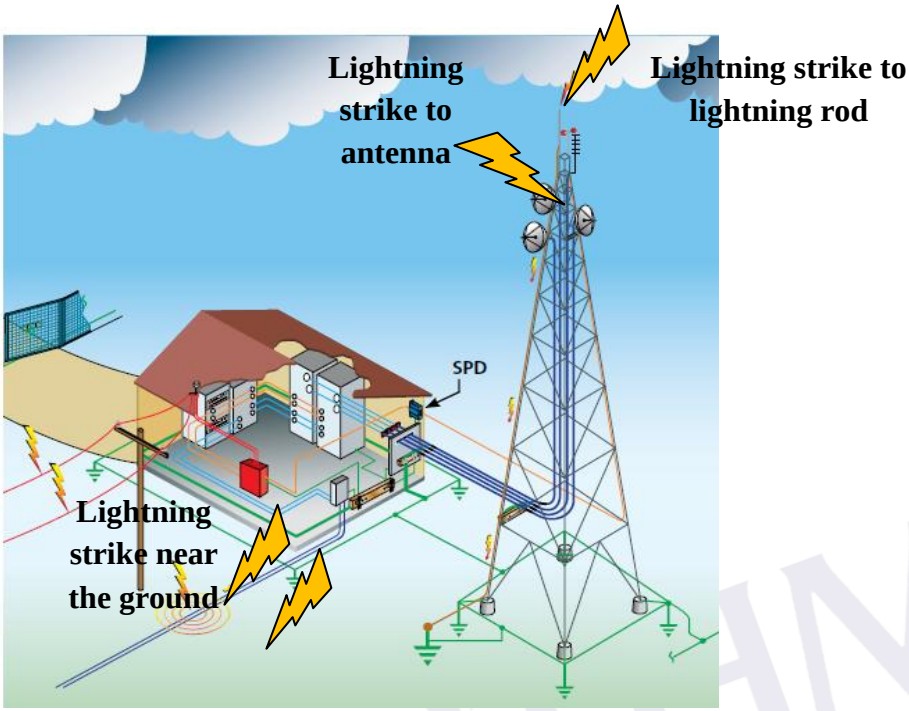


Figure 2.1: Illustration of the lightning strike [9]

2.1.1 Lightning Strike to the Lightning Rod or Tower

When the lightning strike directly to the lightning rod or to the tower, the surge current will flow through the down conductor and dissipated into the ground. The impedance of the ground and the current flowing through it creates large difference of potential (over voltages). If the rise in tower potential is significant enough, then a flashover to the antenna and radio transmission line will occur. The over voltages will propagate into building via cables thus damaging the equipment inside the building.

Direct lightning stroke to the communication tower gives the higher over voltage than the lightning stroke on distribution overhead line and also higher than the induced voltage surge. Lightning usually attaches at the lightning rod causing interference in other conductors. Induced over voltages by lightning on overhead telephone line cause damages to both telephone system and electronics equipments connected to the telephone line.

2.1.2 Lightning Strike to the Antenna

A direct strike to the antenna or radio transmission line will cause localised damage to itself. The damage of this equipment is called as shielding failure, also known as the shielding failure rate (SFR). Generally, the SFR is defined as the rate of flashes per 100 km of line per year [8].

When an antenna tower is struck by lightning, the electric potential near the grounding electrode rises and the lightning surge flows backward to equipment through other grounding electrodes. Further, flashover current flows to the distribution lines or signal lines through arresters or protection devices. In case an antenna tower is on the roof of the station, the lightning conductor is connected to the steel frame of the building. The lightning surge is therefore shunted to the building and further lightning surge enters other grounding systems through contact with equipment support hardware. The lightning surge current from direct strike on a steel tower is about ten times as large as the lightning surge current from distribution lines .Typically, the lightning rod is mounted on top of the tower structure. In certain communication sites, the lightning rods are mounted near the antenna to protect it from a direct strike.

2.1.3 Lightning Strike near Ground

When the lightning strike on the ground, it will cause an increment of the earth potential, which can spread to the installation. Power equipment is for telecommunications which uses for power as its input source, is easily damaged by lightning from power distribution lines. Lightning surge can bother the communication station for AC power line supplied for the system indirectly when lightning hits the distribution lines and induced voltage on communication cables which can damage the communication equipments inside the communication station. The over voltages can affect the electrical equipment if there are no voltage protectors [10].The lightning over voltage depends on the lightning current itself, system parameters such as system structures, grounding resistance, grounding methods, equipments and also the protecting equipments.

2.2 The Lightning

Lightning can be defined as a transient, high current discharge that builds up on clouds near the surface of earth whose path length is generally measured in kilometre. It occurs when some region of the atmosphere attains an electric charge sufficiently large which come with electric field contain charge cause electrical breakdown.

The lightning discharges, that formed in the thunderclouds and seen as a flashes and strike toward the ground. The lightning is happen when the negative charge in cloud become great enough, it seeks an easy path to positively charged ground on below [11].Typically, this phenomenon occurs during bad weather in which can be generated by volcanic eruption, dust storms and sometimes during the snow storm.

It is common that human beings have looked at lightning as an object of awe for it destructive capabilities and can be attractive phenomenon. It is also known that the lightning is very dangerous because it can damage property and the most terrifying life and death.

2.2.1 The Creation of the Lightning

Overhead clouds and the earth structure such as ground, tower, tall building, and tree forms two electrodes, anode and cathode. Then, the long air column between them reacts as the breakdown channels (phase to earth). Lightning flashes also occur between the thunderclouds known as phase to phase. The negative charge in cloud seeks an easy path to positively charged ground on below.

The lightning discharges can be divided into two categories which are cloud flashes and ground flashes. The cloud flash happens when the lightning discharges happen in cloud where it came in contacts within the thunderclouds. The cloud flashes consist of intra cloud flashes, air discharge and inter cloud flashes as showed in figure 2.2 [8].

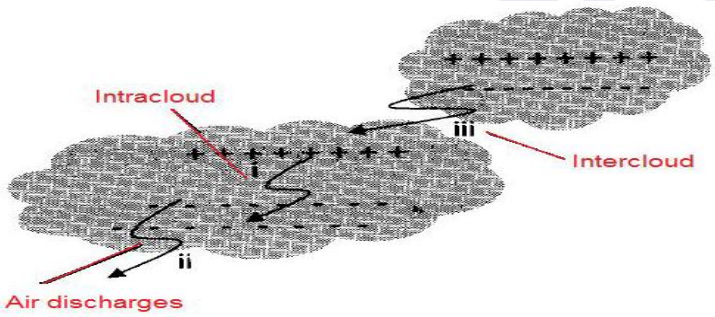
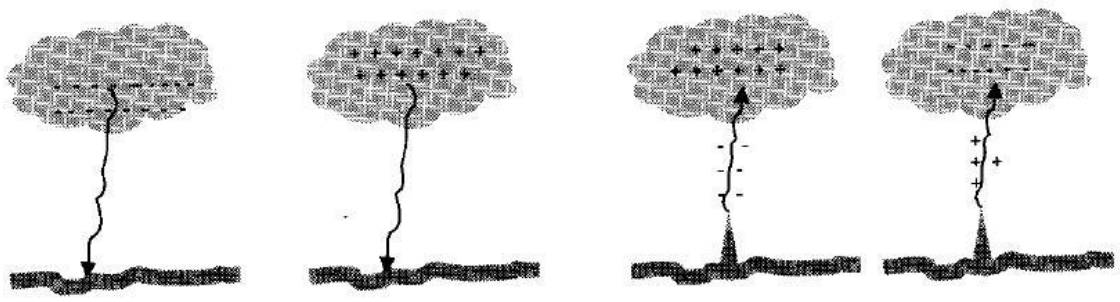


Figure 2.2: The illustration of the cloud flash [8]

In ground flash, the lightning was discharged to make contact with the earth object in which the earth objects contain of positive charges. The protections to the equipment in power system are very important to avoid the lightning flash's damages in which it has destructive capability to destroy the equipment. The ground flash can be divided into four categories which are downward negative, downward positive, upward negative and upward positive. The ground flash is illustrated as in figure 2.3.



(a) (b) (c) (d)

Figure 2.3: The illustration of lightning flash [8]

(a) Downward negative

(b) Downward positive

(c) Upward positive

(d) Upward negative

The cloud contains of small and large drops of water. The large drops (diameter less than 0.3cm) descend with higher velocity due to the gravity [8]. In the atmosphere under fair-weather condition, the normal electric field exists. For the charge formation in the cloud, the large drops of water are polarized by induction with the ions exist in the cloud. This interaction caused the charges separation, where the upper side of the cloud carries positive charges and the lower portion side carries negative charges. The creation of the flash can be divided into two groups, the first stroke and the second stroke [12].

2.2.2 The Creation of First Stroke

The cloud from lower portion side carries a negative charge. These clouds grow into a thunderstorm, and contain more negative electrons form. When the storm clouds approached the earth, where the ground underneath these clouds is positively charged, the opposite charge will attract each other. The negative charge of the clouds will attract more positive electrons on the ground until finally there is a large enough charge of these opposite electrons. Then this huge energy will be released known as lightning. The illustration can be seen as showed in figure 2.4.

Occurrence of lightning strike started when a negative charged channel jumps out of the cloud and is called a step leader**.** The stepped leader moves towards the earth in halting steps about 50 meters and after 50meter, it will pause. After that, it

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